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Annex A — Earth Base-Case Validation for the Quantum Hash Descriptor (QHD)

Scope

This annex documents a complete base-case validation of the Quantum Hash Descriptor (QHD) using Earth as a fully specified reference object. The purpose of the annex is to demonstrate that the QHD workflow can be executed deterministically from declared physical inputs through entropy normalization, continuous descriptor construction, canonical serialization, and SHA3-256 hashing under a fixed protocol policy [cite:18][cite:46][cite:49][cite:52].

The annex is intended as a proof-of-concept validation artifact rather than as a claim of final physical completeness. In particular, the Earth informational state used here is an explicitly declared toy construction designed to remove ambiguity and permit independent replication of the pipeline [cite:43].

Validation objective

The validation objective is to show that the Earth base case satisfies four minimum proof-of-concept requirements: deterministic computation, reproducible serialization, stable hash generation, and transparent traceability of all inputs and assumptions [cite:82][cite:83][cite:96]. In NASA Technology Readiness Level language, this type of exercise is consistent with an analytical and computational proof of concept at approximately the TRL 3 level, with potential extension toward TRL 4 once the workflow is exercised in broader data environments [cite:82][cite:83].

Declared inputs

The Earth validation case uses the following declared inputs and conventions.

Field	Value
Object name	Earth
Object class	planet
Reference frame	SSB
UTC epoch	2024-01-01T00:00:00Z

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TAI-UTC offset	37 s [cite:46][cite:49][cite:52]
Serialized atomic time	1704067237
Earth mass	5.9722e24 kg [cite:18]
Serialization version	QHD-1.0
Hash function	SHA3-256 [cite:7][cite:13]

The UTC epoch is transformed into the serialized time value by adding the declared TAI-UTC offset to the Unix second count for the selected UTC instant. This does not imply that Unix time is the only acceptable QHD time basis, but it demonstrates one unambiguous and reproducible serialization policy for proof-of-concept purposes [cite:46][cite:49][cite:52].

Informational state definition

The QHD framework defines an effective state representation $P_0(t)$ with positive, normalized structure [cite:1]. For this validation case, $P_0(\text{Earth})$ is implemented as a classical three-compartment probability state based on approximate internal mass partitioning of Earth, using core = 0.31, mantle = 0.68, and crust = 0.01 [cite:43].

This yields the declared normalized state:

$$P_0(\text{Earth}) = \{0.31, 0.68, 0.01\}.$$

The operational entropy is computed using the Shannon-form expression

$$S = -\sum_i p_i \log\, p_i,$$

with normalization

$$S_{\max} = \log\, N, N = 3,$$

so that

$$S_{\text{norm}} = \frac{S}{S_{\max}}.$$

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Under this declared policy, the Earth base case yields $S_{\mathrm{norm}} = 0.6111063202$ [cite:57]. This value is protocol-dependent and should be interpreted as a deterministic result of the declared partition, not as a universal Earth constant independent of model design [cite:56][cite:57].

Energy anchor and continuous descriptor

The energetic anchor is defined by

$$E_0 = Mc^2,$$

using Earth mass and the exact speed of light [cite:18]. For the Earth base case, this yields an energy scale of 5.36656656e41 J and a logarithmic energy term of 41.7297757490 [cite:57].

The demonstration parameters are fixed as follows:

Parameter	Value
K	1.0
γ	1.0
S_{ref}	0.5
$C(t)$	1

Using the QHD continuous descriptor policy,

$$\mathrm{Re}(H_{\mathrm{cont}}) = \log_{10}(E_0) + \frac{K}{100}(S_{\mathrm{norm}} - S_{\mathrm{ref}}),$$

$$\mathrm{Im}(H_{\mathrm{cont}}) = \gamma S_{\mathrm{norm}},$$

the Earth base case yields the following values [cite:57]:

Component	Value
$\log_{10}(E_0)$	41.7297757490 [cite:57]
S_{norm}	0.6111063202 [cite:57]
$\mathrm{Re}(H_{\mathrm{cont}})$	41.7308868122 [cite:57]

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$\mathrm{Im}(H_{\mathrm{cont}})$	0.6111063202 [cite:57]

The resulting continuous descriptor is therefore

$$H_{\mathrm{cont}}(\mathrm{Earth}; t) = 41.7308868122 + i\ 0.6111063202.$$

Canonical serialization policy

The Earth base-case validation uses a fixed serialization policy intended to eliminate ambiguity in hash generation. The policy is defined as follows [cite:1][cite:56]:

- Encoding: UTF-8.
- Data format: JSON.
- Key order: lexicographically sorted.
- Delimiters: compact separators without extraneous whitespace.
- Floating-point representation: fixed scientific-notation strings for relevant scalar fields.
- Unit-bearing field names: explicit, such as `M_kg` and `T_TAI_unix_s`.
- Metadata inclusion: object name, object class, reference frame, epoch string, and serialization version retained in the serialized structure.

This policy is important because reproducibility depends not only on equations but also on formatting stability. Two mathematically identical states can yield different hashes if number formatting, key order, or omitted metadata differ between implementations [cite:94][cite:96].

Canonical Earth JSON

Under the declared policy, the canonical Earth serialization is the following JSON object [cite:55][cite:56]:

{"C":1,"H_cont":{"Im":"6.11106320e-01","Re":"4.17308868e+01"},"M_kg":"5.97220000e+24","T_TAI_unix_s":1704067237,"epoch_utc":"2024-01-01T00:00:00Z","object_class":"planet","object_name":"Earth","reference_frame":"SSB","serialization_version":"QHD-1.0"}

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This serialized object functions as the reference test vector for the Earth base case under QHD-1.0 [cite:55][cite:56].

SHA3-256 result

Applying SHA3-256 to the UTF-8 byte sequence of the canonical JSON yields the following digest [cite:55][cite:57]:

```
4be65a8add8b7b74b184afe2b0b3ef7d068276e6e8ea1f399a75adb630e23510
```

Recalculation under the same assumptions reproduces the identical digest, which validates determinism of the Earth reference case at the level of computation and serialization [cite:57][cite:96].

Validation criteria and outcome

The Earth base case is considered validated for Phase 1 of the proof of concept if the following criteria are satisfied.

Criterion	Result
Same declared inputs produce same descriptor values	Passed [cite:57]
Same canonical JSON produces same SHA3-256 digest	Passed [cite:55][cite:57]
All key assumptions are explicit and inspectable	Passed [cite:56]
Time convention is declared and reproducible	Passed [cite:46][cite:49][cite:52][cite:57]
Informational state construction is explicit	Passed [cite:43][cite:56][cite:57]

On this basis, the Earth case functions as a valid reference implementation for the first phase of QHD proof-of-concept testing. The result does not yet validate universal applicability across all astronomical object classes, but it does validate the internal consistency and operational reproducibility of the QHD pipeline for one complete worked example [cite:82][cite:83][cite:96].

Interpretation

The most important outcome of this annex is not the specific numerical value of the Earth hash, but the fact that the full chain from object definition to final digest is transparent, deterministic, and

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independently reproducible [cite:56][cite:57][cite:96]. That property is essential if QHD is to be evaluated as a provenance and identity layer for scientific archives, simulations, and cross-platform synchronization workflows [cite:3][cite:12].

The annex also clarifies a key conceptual point: the deterministic identity produced by QHD is protocol-dependent rather than metaphysically absolute. If the informational partition, normalization policy, or serialization rules are changed, the output may change as well; such changes must therefore be versioned and documented rather than introduced silently [cite:56][cite:57].

Limitations

This validation uses a toy informational state rather than a geophysically exhaustive Earth state model, so it should be interpreted as a controlled reference case rather than as a final scientific ontology of Earth structure [cite:43][cite:56]. The annex also validates one epoch and one object only, which is sufficient for Phase 1 but not for demonstrating inter-object discrimination, temporal chaining across multiple epochs, or robustness across heterogeneous astronomical classes [cite:82][cite:83].

A stronger subsequent phase would apply the same frozen protocol to Mars and Jupiter, then to multiple epochs per object, thereby testing both object separation and multi-snapshot chaining under the same deterministic policy [cite:18][cite:30][cite:32].

Annex status

This annex may be used as the formal Phase 1 validation record for the Earth reference case under QHD-1.0. It is suitable for inclusion in a larger scientific manuscript, institutional concept note, or technical proof-of-concept dossier concerned with deterministic astronomical identity and provenance [cite:82][cite:83][cite:96].

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